In the Specification:

Please amend the specification by substituting the paragraphs indicated below for the paragraphs as previously presented. Amendments to the specification are shown with additions underlined and deletions in [brackets].

Please replace the paragraph beginning at page 1, line 12 with the following paragraph:

This application is a continuation of U.S. Application Serial No. 09/643,898, filed on August 18, 2000, entitled "Vibrotactile Haptic Feedback Devices" and also[This application] claims priority to U.S. Provisional Application No. 60/149,782, filed August 18, 1999, entitled "Vibration Force Feedback Device Implementations," and which is incorporated by reference herein, and this application is a continuation-in-part of copending U.S. Patent Application No. 09/608,125 [09/________], filed June 30, 2000, entitled, "Controlling Vibrotactile Sensations for Haptic Feedback Devices," which claims priority to U.S. Provisional Application No. 60/142,155, filed July 1, 1999, all of which are incorporated by reference herein.

Please insert the following paragraph on page 1, before the heading "BACKGROUND OF THE INVENTION":

STATEMENT REGARDING FEDERALLLY SPONSORED RESEARCH

Certain inventions described herein were made with Government support under Contract Number N000014-98-C-0220, awarded by the Office of Naval Research. The Government has certain rights in these inventions.

Please replace the paragraph beginning on page 9, line 34 and continuing onto page 10 with the following paragraph:

Other input devices 39 can optionally be included in interface device 14 and send input signals to microprocessor 26 or to host processor 16. Such input devices can include buttons, dials, switches, levers, or other mechanisms. For example, in embodiments where the device 14 is a gamepad, the various buttons and triggers can be other input devices 39. Alternatively[Or], if the user manipulandum 34 is a joystick, other input devices can include one or more buttons provided, for example, on the joystick handle or base. Power supply 40 can optionally be

coupled to actuator interface 38 and/or actuators 30 to provide electrical power. A safety switch 41 is optionally included in interface device 14 to provide a mechanism to deactivate actuators 30 for safety reasons.

Please replace the paragraph beginning on page 12, at line 18 and continuing onto page 13 with the following paragraph:

A different implementation for controlling a rotating mass provides a bi-directional mode, in which the mass is rotated harmonically or in two directions to provide vibrotactile sensations. The motor can be controlled by a drive waveform that changes between positive and negative signs, thereby changing the direction of rotation of the motor shaft 102 in accordance with the waveform. In one method of operation, the eccentric mass 104 never completes a full rotation, but is instead controlled to oscillate approximately about a single point in its range of motion (a forced harmonic). The eccentric mass thus travels through only a portion of the full range of motion of the shaft before it changes direction and moves in the opposite direction. This causes a vibration in the motor and in any member or housing coupled to the motor as the mass is quickly moved back and forth. The dynamic range of control is much greater in bi-directional mode than in the prior art uni-directional mode, allowing more finely-tuned and precise sensations to be output. Also, this embodiment allows independent control of the magnitude and frequency of the vibrotactile sensations (vibrations/acceleration of the housing), providing a much greater range of sensations to the user. The controller can adjust the magnitude of the drive waveform to correspondingly adjust the magnitude of output vibrations, and the controller adjust the frequency of the drive waveform independently of the amplitude of the drive waveform to adjust the frequency of vibration. This embodiment is described in greater detail in copending application no. <u>09/608,125</u> [09/________], filed June 30, 2000, entitled, "Controlling Vibrotactile Sensations for Haptic Feedback Devices," and which is incorporated herein by reference. This bi-directional control may be used to drive linear-moving and oscillating masses as described in several of the embodiments described below.

Please replace the paragraph beginning on page 13, at line 19 with the following paragraph:

Forced harmonic driving may consume significantly higher power than continuous rotation of the motor/mass for the same vibration magnitude. Some <u>of</u> this effect is mitigated by

driving the mass near the resonance frequency of the harmonic system (if compliance is provided). In addition (or alternatively), in one embodiment, both uni-directional and bi-directional modes can be used in a single device, alleviating some power consumption as well as providing more compelling haptic sensations. A given actuator's value can be maximized in a device by driving the actuator/eccentric mass continuously to get large magnitude vibrations from 5 to 80 Hz and then switch to a forced harmonic (bi-directional) mode to produce high frequency vibrations. This multi-mode approach can provide higher bandwidth and opens up a whole range of haptic effects. Continuous rotation does not provide independent command of magnitude and frequency, but may still be very compelling in combination with the bi-directional mode. For example, the actuator can be commanded to produce a 10 g 5 Hz vibration with the uni-directional mode, followed a command to produce a high frequency decaying ringing to simulate loss of vehicle control followed by impact with a metal guard rail. Choosing a different combination of motor and mass may allow the crossover frequency to be changed, where one drive mode is switched to the other. A H-bridge amp and a tachometer can be used both to control the velocity in continuous rotation via an external control loop and then use the same motor amp to drive the motor harmonically with independent control of frequency and magnitude. In other embodiments, one actuator in the device 14 can operate in uni-directional mode, and another actuator can operate in bi-directional mode, allowing a uni-directional vibrations to be output at different times or simultaneously.

Please replace the paragraph beginning on page 14, line 20 with the following paragraph:

Some embodiments of the present invention allow the compliance of a suspension that couples the vibrating mass and/or actuator to a ground, such as the device housing, to be varied. In harmonic system including a spring coupled to a mass (ignoring damping for present purposes), the greatest magnitude vibrations are output near a resonance frequency of the system that is determined by the amount of mass and by the compliance of the spring. If the compliance in the system is changed, then the resonant frequency (natural frequency) of the system is changed; if the input drive waveform remains the same, the amplitude of resulting vibrations is reduced due to the new physical properties of the oscillating system, i.e., if a frequency near the old resonant frequency is used, a diminished magnitude is output from the system. A different drive signal frequency near the new resonant frequency can be input to provide the greatest

magnitude vibrations.[.] Changing compliance thus allows different magnitudes to be output, and also allows different drive frequencies of vibrations to achieve more efficient high magnitudes.

Please replace the paragraph beginning on page 17, at line 23 with the following paragraph:

FIGURE 6 is a schematic view of a different embodiment 172 of an actuator assembly which provides a variable flexibility between mass and housing. A grounded rotary actuator 173 rotates a lead screw 174. A clamp 175 is coupled to the lead screw 174 at a threaded bore 176 in the clamp so that the clam 175 moves along the lead screw as the screw is rotated. A cantilever 176 is grounded at one end, is threaded through rollers 177 or other clamp elements, and is coupled to a magnetic mass 178 at its other end. A coil 179 and core 181 are grounded and positioned adjacent to the mass 178. When a current is flowed through the coil 179, the magnetic force causes the mass 178 to move; driving current having a forcing function causes the mass 178 to move back and forth as shown by arrows 183, causing a vibration in the housing. This configuration allows independent control over frequency and magnitude of the vibrations when inputting different drive waveforms. The cantilever 176 is flexible and bends to allow the mass 178 to move. Operating a second order system at the natural frequency is very power efficient because it <u>takes</u> [take] very little energy to keep a harmonic motion going. The system may also be driven off of the resonant peak frequency.

Please replace the paragraph beginning on pages 19 at line 33 and continuing on page 20 with the following paragraph:

A grounded motor 202 has a rotating shaft that is rigidly coupled to a rotating spindle 204. A flat keyed hub 206 of the spindle extends above the surface of a flat spindle portion; a cross section of the flat key portion 206 is shown in FIGURE 8b. A shaft portion 208 of the spindle 204 extends up from the flat spindle portion and a lead screw 210 is coupled to the spindle shaft portion 208, allowing the spindle to act on a centering platen 212. The centering platen 212 includes a threaded portion 214 which engages threads of the lead screw 210. An eccentric slotted disc 216 is positioned loosely around the shaft portion 208 and flat keyed hub 206 of the spindle 204. The slotted disc 216 is shown in overhead view in FIGURE 8c, and has a number slots 218 extending radially from the center aperture 220 of the disc, where the center

aperture 220 is made large enough to accommodate the keyed hub 206 as shown. Four slots 218 are shown in Fig. 8c, each slot a different length, and each slot wide enough so that the narrow dimension of hub 206 can slide therein if aligned with the slot. The disc 216 can <u>have</u> other shapes and have different numbers of slots in other embodiments.

Please replace the paragraph beginning on page 20, at line 15 with the following paragraph:

In operation, the assembly 200 causes the disc 216 to lock into place in different positions, thus providing different eccentricities. The actuator 202 is caused to rotate the spindle 204 in one direction, such as clockwise. This causes the platen 212 to raise, which in turn causes the portion 226 of the platen to engage the sloped portion 224 of the foot 222. This engagement causes the tip 223 of foot 222 to pivot inward and move the disc 216 so that the keyed hub 206 moves into one of the slots 218 that is aligned with the narrower dimension of the keyed hub.[.] The disc need not be moved the entire length of a slot 218, since centripetal force during rotation will force the disc to move any remaining length. The motor is then rotated clockwise to cause the disc 216 to rotate with the spindle. The thread of the platen eventually runs off of the shaft, allowing continuous rotation of the mass and vibrations to the output. Since the center of the disc 216 is not aligned with the axis of rotation of the motor shaft, an eccentric force is produced, which is transmitted to the housing (ground) and to the user. The disc remains in place during rotation due to centripetal force. The foot 222 is preferably located as to not interfere with rotation in its pushed-in position.

Please replace the paragraph beginning on pages 22, at line 32 and continuing onto page 23 with the following paragraph:

FIGURE 11b is a top plan view of the rotating disc 316, and shows a number of steel balls 320 positioned in the disc 316. The rotating disc has a pocket 317 cut on its underside around its outer circumference with a multiplicity of spherical pockets 322 cut into the outside wall of this pocket. [spherical pockets provided in the rotating disc.] FIGURE 11c shows a section of rotating disc 316 and the spherical pockets 322.